

See, e.g., S.M. Cassidy (ed.), Elements of Practical Coal Mining 76-77 (1973). Certainly, a major means of detecting loose roof is the one employed by the inspector in this matter: the sound-and-vibration method, which is a simple test involving tapping the roof with a hammer. Generally, loose roof will give off a dull, hollow, drummy sound as compared with the solid ring of firm roof. While a drummy sound is generally an indication of loose roof, circumstances may be present in which the sound-and-vibration test is not reliable. See, e.g., Cassidy, id., at 77. We note the concession of Inspector Bays that there are instances when a drummy sound is produced during testing but the roof is not, in fact, loose. Tr. 64-65.

In this regard, it bears emphasis that Amax's mine is a potash mine. Unlike the regulatory scheme that obtains with respect to underground coal mines, approved roof control plans are not required in underground metal-nonmetal mining operations. Rather, "[g]round support shall be used if the operating experience of the mine, or any particular area of the mine, indicates that it is required." (30 C.F.R. §57.3020 (1985) (formerly numbered as 30 C.F.R. § 57.3-20 (1984)). See generally, White Pine Copper Div., Copper Range Co., 5 FMSHRC 825, 835-37 (May 1983). (Of course, the standard involved in the present case also imposes the continuing duty to examine ground conditions in such mines and to take down or adequately support any loose ground.)

In view of the distinctive nature of ground control in metal-nonmetal mines and the uncertainties that may be involved in any particular sound-and-vibration test, and on the basis of the present record, a per se rule equating drumminess with loose ground in underground metal-nonmetal mines cannot be endorsed. Rather, we hold that in evaluating ground conditions and the adequacy of support under this standard, all relevant factors and circumstances must be taken into account. The result of a sounding test is an important factor, but is not necessarily dispositive. The size of the drummy area and other possible explanations for the drumminess must also be considered. Visible fractures, sloughed material, "popping" and "snapping" sounds in the ground, the presence, if any, of roof support, and the operating experience of the mine or any of its particular areas, are also relevant factors to be considered. Cf. White Pine, supra, 5 FMSHRC at 833-37.

In the present case, we conclude that substantial evidence, which includes but is not limited to the inspector's sounding test, supports the judge's finding that the cited ground was loose. Here, the inspector carefully examined the area of roof in question. His attention was engaged first by the presence of a clearly visible crack surrounded by 8 to 10 previously installed roof bolts. A fracture often signifies loose roof, and Amax's previous bolting efforts indicated some level of concern by the operator itself. As noted, the inspector's sound test produced a drummy sound despite the existing bolting. The testimony of production superintendent Desai regarding ground conditions in Amax's mine lends